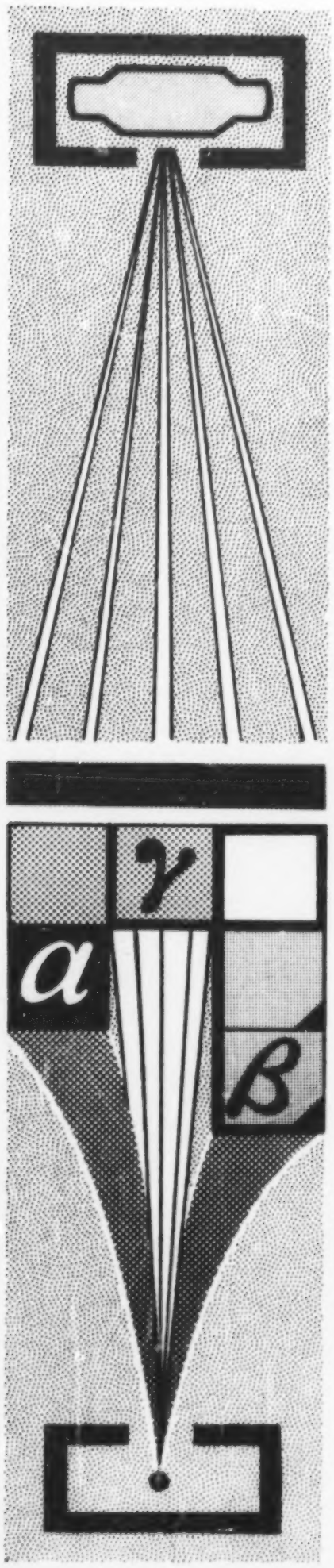

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DEVELOPMENT and EVALUATION of an AUTOMATIC COLLIMATOR for MEDICAL DIAGNOSTIC X-RAY MACHINES

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MORP 68-9

DEVELOPMENT and EVALUATION of an AUTOMATIC COLLIMATOR for MEDICAL DIAGNOSTIC X-RAY MACHINES

by

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AUGUST 1968

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Control Administration
National Center for Radiological Health
Rockville, Maryland 20852

MEDICAL AND OCCUPATIONAL RADIATION PROGRAM

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MORP 68-8	Dental X-ray Teaching and Training Replica
MORP 68-9	Development and Evaluation of an Automatic Collimator for Medical Diagnostic X-ray Machines
MORP 68-10	Survey of the Use of Radionuclides in Medicine: Preliminary Report

FOREWORD

The National Center for Radiological Health conducts a national program for the prevention and control of radiological hazards to public health through (1) surveillance activities, (2) research and development programs, (3) technical assistance to governmental and other organizations, (4) technical training programs, (5) development of criteria and codes, (6) administration of grants, (7) consultation on international programs, and (8) public information and education activities.

The Medical and Occupational Radiation Program is the component of the Center which deals with reduction of unnecessary radiation exposure of patients, workers, and others incidentally exposed by the use of X-rays, radioactive materials, radiopharmaceuticals, and particle accelerators.

The Center publishes its findings in Radiological Health Data and Reports (a monthly publication), the Environmental Health Series, Public Health Service numbered reports, appropriate scientific journals, and Program and Branch technical reports.

The technical reports of the Medical and Occupational Radiation Program (MORP) allow comprehensive and rapid reporting of the results of inhouse and contractor projects. The reports are distributed to State and local radiological health program personnel, Center technical staff, Center advisory committee members, University radiation safety officers, libraries and information services, industry, hospitals, laboratories, schools, the press, and other interested individuals. These reports are included in the collections of the Library of Congress and the Clearinghouse for Federal Scientific and Technical Information.

I encourage the readers of these reports to inform the Center of any omissions or errors. Your additional comments or requests for further information are also solicited.

James G. Terrill, Jr.
Center Director

PREFACE

This report describes the design of the second prototype of an automatic collimating system for diagnostic X-ray machines. Results of a clinical evaluation of this prototype are discussed and the resulting improvements are described. In its present design the collimator can automatically provide optimum collimation for the types of examination which account for about 75 percent of the number of diagnostic medical radiographs on a national basis. The system, which utilizes a commercially available motorized collimator, may be installed on any X-ray unit which will accept the motorized collimator.

The concept of reducing patient dose by means of automatic collimation, as demonstrated in this successful working prototype, should be of interest to State health personnel and others concerned with radiological health.

John C. Villforth
Chief, Medical and Occupational
Radiation Program

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INTRODUCTION

A recent report by Penfil and Brown stated that the genetically significant dose from medical diagnostic X-rays could be reduced from 55 to 19 millirads if the size of the X-ray beam in the plane of the film were limited by collimation to the film size (*1*). This information was based on data collected by the U.S. Public Health Service in its 1964 Study of Population Exposure to X-rays in the United States (*2*). This study also showed that about 51 percent of all nondental radiographic examinations involve the chest, 11 percent the upper abdomen, and 14 percent the lower abdomen. All of these examinations use either the chest cassette or the Bucky tray. Thus, an automatic collimating system which could adjust the X-ray beam size to film size for films in both the chest cassette and the Bucky tray would be applicable to at least 75 percent of the exposures in diagnostic radiology.

In response to the findings of the 1964 study, a prototype automatic X-ray collimating system was developed at the X-ray Exposure Control Laboratory in 1966 (*3*). This system demonstrated the technical feasibility of such a device and provided insight into the problems involved in its further development.

To determine the acceptability of this device in a clinical situation, a second automatic collimation system was built at the Laboratory and installed on a radiographic X-ray unit in the Radiology Department of the Clinical Center at the National Institutes of Health in February 1967. It has been used since then, with some improvements added as their need became apparent. This report will discuss the essential aspects of the development and clinical evaluation of the automatic collimator installed at the NIH.

THEORY OF OPERATION

The automatic collimator installed at the NIH has the same principles of operation as the original prototype discussed in an earlier paper (*3*). It has some added features, however, which help to make it much more useful in a clinical situation. The automatic control system of both the original prototype and the NIH model consists of four basic mechanisms: 1) a cassette size detector, 2) a motorized X-ray collimator, 3) a pair of servo-amplifiers, and 4) a focal spot-to-Bucky plane distance compensating unit. The cassette size detector is a modified Bucky tray for a radiographic unit. When a cassette is placed into the Bucky tray, relays corresponding to the length and width of the cassette send two electrical signals, proportional to the cassette dimensions, to the servo-amplifiers. In addition, the motorized collimator sends the servo-amplifiers a pair of signals which indicate the positions of the two sets of collimator shutters.

For each dimension of the cassette, the following sequence occurs: 1) the signals from the collimator and Bucky tray are compared and amplified, 2) the amplified signal difference energizes the collimator motor to drive the shutters in the direction which will reduce the signal difference, 3) the signal difference becomes zero when the shutters reach the position defined by the cassette in use, at which point the motor stops. The overall effect is that when a cassette is placed into the Bucky tray, the cassette dimensions are compared with the shutter positions, and the motors run until the proper positions are reached. When the cassette is removed, the shutters close to a preselected minimum opening that is large enough to allow the technician to use the optical beam localizer before a cassette is placed into the tray. Adjustment of the shutter positions for changes in focal spot-to-Bucky plane distance is accomplished by a potentiometer which senses height and consequently varies the voltage applied to the cassette size detector.

The system includes the capability for horizontal radiography. When the X-ray tube is positioned at the proper horizontal distance, a microswitch disconnects the focal spot-to-Bucky plane distance compensating circuit, and a circuit for a preset horizontal distance is then activated. A 40-inch focal spot-to-film distance is used for horizontal radiography on the X-ray unit at the NIH. However, the automatic collimator may readily be adapted to any distance used, for example, the standard 72-inch distance for chest radiography.

DEVELOPMENT

Cassette Size Detector

The first cassette size detector (figure 1) of the automatic collimator installed at the NIH resembles the cassette size detector of the original automatic collimator previously reported (*3*). The detector of the original automatic collimator had a dual staircase clamp mounted on both the front and rear cassette clamp of the Bucky tray. Cassette size was sensed with a series of microswitches, one at each step on both sides of the rear clamp. In the detector of the collimator installed at the NIH, a flat brass contact was substituted for each of the microswitches. The metal frame of the cassette then makes the appropriate contact and actuates relays that perform the same function as the microswitches. A second group of contacts is located on the underside of the Bucky tray and is responsible for sensing the transverse dimension. The contacts in this group are actuated one-by-one as the arm of the tray's cassette-centering mechanism moves in and out for varying cassette sizes. The centering ability of the dual staircase-shaped clamp was the same in both detectors, but the switching activity was moved from the detector into a control box in the system at the NIH.

For reasons discussed in the following section, X-ray technicians at the NIH objected to the staircase-shaped clamps of the cassette size detector. Therefore, these clamps were removed and a rectangular bakelite

strip was attached to the rear clamp of the Bucky tray, as illustrated in figure 2. The bakelite strip contains a series of spring-loaded brass pins on one side of the center, to detect cassette size. Pins are required on one side only because technicians normally center cassettes in the cassette clamps. This system has been used without difficulty since it was installed in the tray.

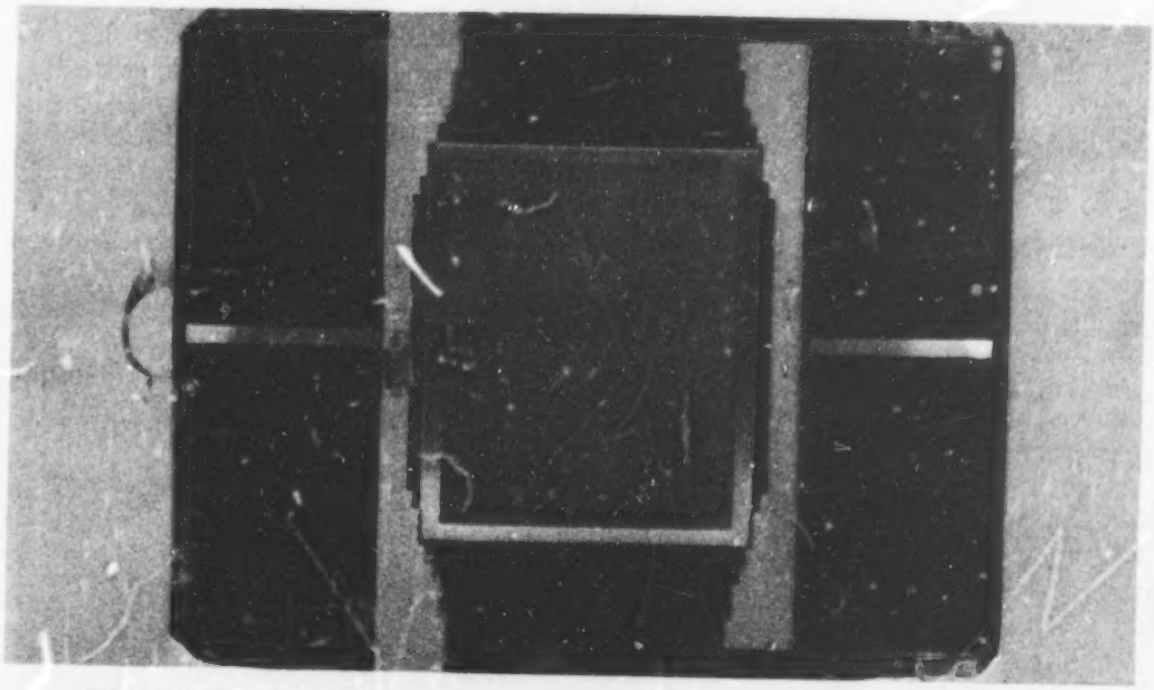

Figure 1. View of Bucky tray with cassette size sensing mechanism utilizing dual staircase cassette clamps, as first installed at the NIH, with cassette in position

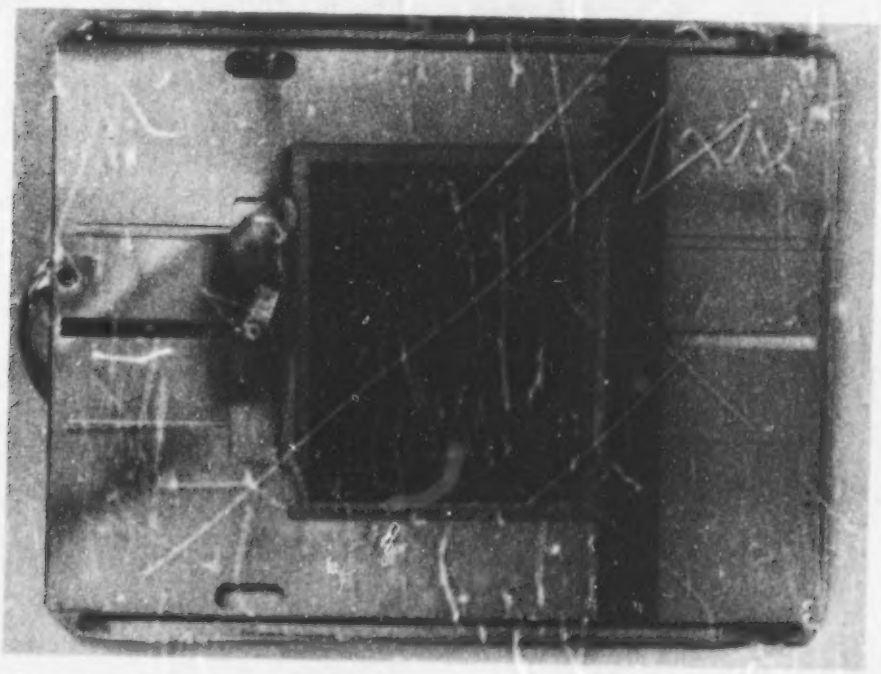

Figure 2. View of Bucky tray with modified cassette size sensing mechanism, with cassette in position

Contact Mechanism

The Bucky tray of the X-ray unit at the NIH, in common with most Bucky trays, may be completely removed from the machine for cleaning and for changing the Bucky grid. In order to retain this feature, a contacting device was necessary to make electrical connections between the cassette size detector and the rest of the system. Because of the tight clearances given the tray in the Bucky slot, it was necessary to place the contacting device on the underside of the tray, as shown in figure 3. No rugged, reliable plug or contact mechanism that met the size requirements was known to exist. This required that one be designed and built in the XECL machine shop. It consists of a pair of contact strips mounted on the underside of the Bucky tray and a corresponding pair mounted on the floor of the Bucky slot in the X-ray unit. Each set of contact strips makes connections for one dimension of the cassette size detector. Each strip on the tray contains a brass contact for each different cassette size to be sensed, plus one common contact. The strips in the Bucky slot contain spring-loaded brass pins which mate with the corresponding contacts on the tray when the tray is in place for making an exposure.

Soon after the automatic collimator was placed in service, it became necessary to install a cabinet-type latch on the tray. This ensured that all of the brass pins made good electrical contact with the contacts on the tray. The tray has been used successfully since then with no major changes in the contact mechanism.

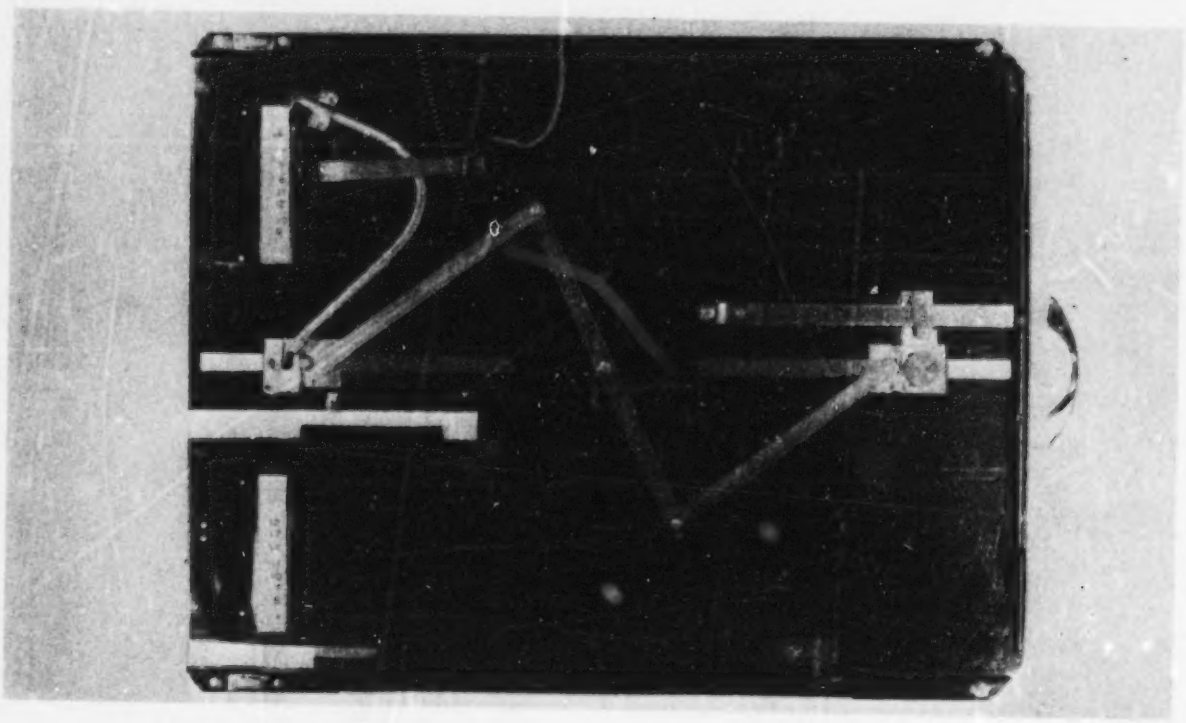

Figure 3. View of underside of Bucky tray

Manual Control Feature

In the original automatic collimator control circuit, provision was made for making exposures using only the Bucky or a wall cassette holder. In addition, no provision was made for reducing the beam size to less than the film size when the area of clinical interest did not include the entire area of the film.

To compensate for these limitations, the automatic collimator installed at the NIH was provided with a mechanism which enables selection of proper beam size for table top exposures. Beam size is selected with pushbutton switches located on both sides of the collimator, as illustrated in figure 4.

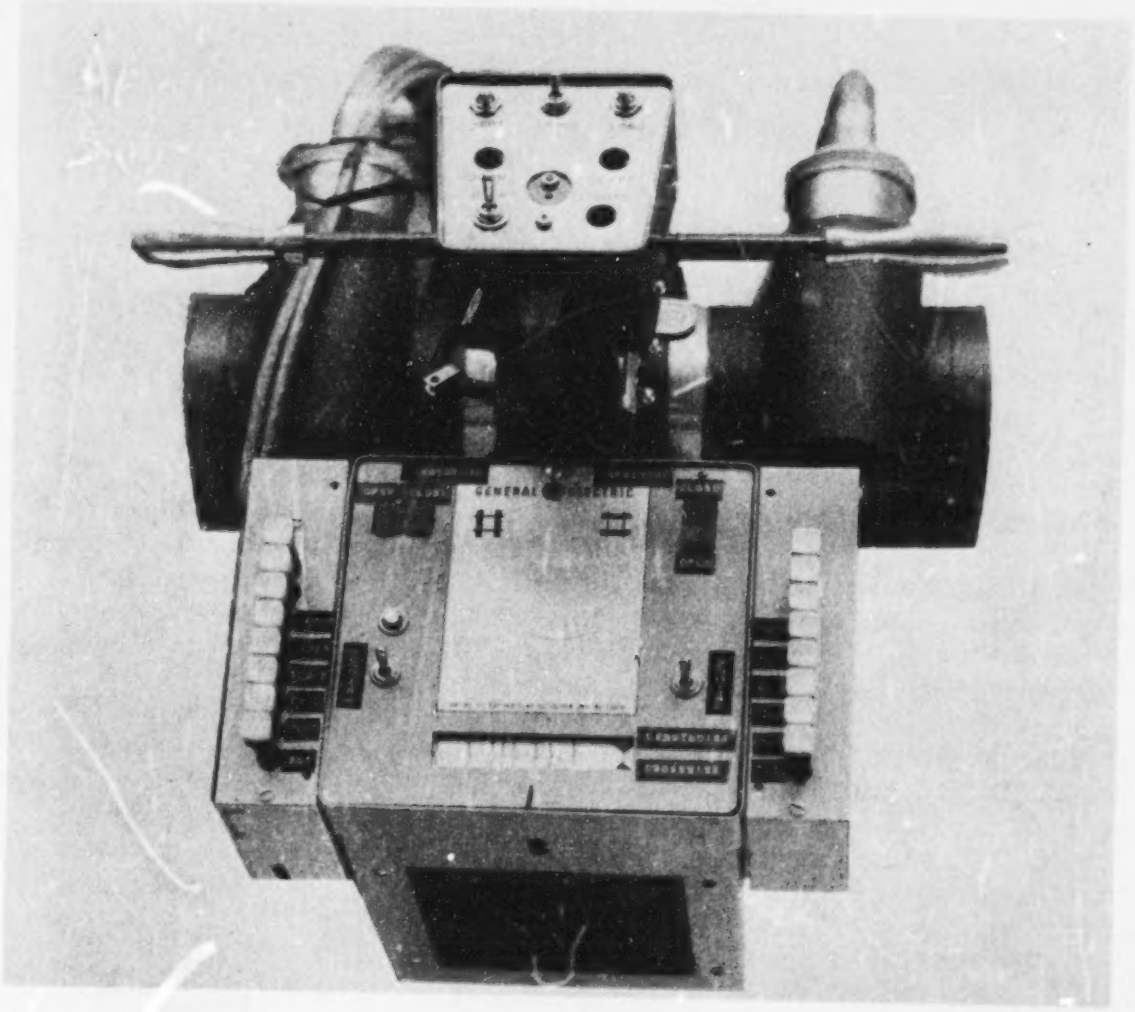

Figure 4. View of collimator head showing pushbutton controls

The panel on the left side is for selecting beam sizes when cassettes are oriented with the long dimension parallel to the length of the table. The other panel is for selecting beam sizes with the cassette rotated 90°. This system enables the technician to select a beam size corresponding to any standard film size at any vertical focal spot-to-film distance for table-top radiography.

To allow technicians to reduce field size to less than the size of the film in use, a toggle switch for each motor-shutter system was installed on the front panel of the collimator. These switches allow the X-ray technician, at will, to shut off the automatic control circuit for either motor-shutter combination and adjust the beam size by depressing the rocker switch associated with a given motor-shutter combination. Depressing the switch one way opens the shutters, and depressing it the other way closes them. This manual control feature is useful for unusual techniques in which the tube is angulated or the Bucky is not used and other setups in which the automatic control feature is not applicable. The manual control feature also permits continued use of the equipment in the event of automatic system failure.

TECHNICIAN EVALUATION

The most important aspect of the automatic collimator is that it be acceptable to the group of people who use it--those involved in radiography. The collimator must be reliable and manageable and must not hinder in any way the efficient use of the X-ray equipment for a wide variety of techniques. It seemed apparent that X-ray technicians using the device routinely in a typical diagnostic suite would soon discover any major shortcomings. Consequently, attempts were made to obtain an objective evaluation of the automatic collimator by technicians who used it.

Following initial installation of the automatic collimator at the NIH and a brief orientation as to its use and limitations, close communication was maintained with the technicians to determine their reaction to the system and to assess any problems which they encountered. They were encouraged to make recommendations for improvements and to point out features of the collimator that were undesirable or troublesome.

Technicians at the NIH generally approved the automatic collimation system. None voiced opposition to the concept and some indicated that they felt it was a valuable tool. The lack of objections was in itself an important indication that automatic collimation could be introduced into other installations with relative ease. Technicians suggested certain modifications which they believed would enhance overall efficiency of the system. These were the principal modifications suggested:

1) The collimator should include a provision for the operator to manually adjust the X-ray beam size to any dimension smaller than the film size used. This is desirable in cases where the area of clinical interest is smaller than the film.

2) A substitute should be found for the nylon staircase cassette clamps. These proved to be unacceptable to the technicians even though they served their technical purposes well. The requested change resulted from the difficulty experienced by the technicians when inserting a cassette into the Bucky tray. When the tray was pulled out to insert a cassette, the rear staircase clamp was not visible. This necessitated sliding the cassette back and forth in the tray in order to locate the proper clamp step on which to place the cassette. This resulted in extra effort and inconvenience compared to using a conventional Bucky tray.

3) A track should be added, to enable the operator to attach a round cone or a lead diaphram to the face of the collimator. A round or oval-shaped beam is preferred to a rectangular or trapezoidal-shaped beam for certain techniques.

Improvements that resulted from these suggestions have been discussed in the Development section of this report.

Since the automatic collimator has limitations in certain techniques, it was necessary to provide the capability of manual operation at the discretion of the technician.

The manual control feature provided what may have been one of the most significant aspects of the collimator evaluation. It was discovered that a number of the technicians developed the tendency to switch the collimator to manual operation and subsequently leave it there--thereby defeating the purpose of the automatic collimator. The source of this problem appeared to be twofold: 1) forgetfulness on the part of the technician to return the collimator to automatic operation when the special procedure was concluded, and 2) distrust of the automatic collimator performance, which was not in all instances unjustified. Early development of the collimator was not without "bugs" as might be expected in the development of any unique piece of equipment involving numerous mechanical and electrical components. This experience points out the extreme importance of system reliability in maintaining user confidence.

The tendency of the technicians to avoid using the automatic feature of the collimator has indicated the necessity of redesigning the system. A method has been developed whereby relays return the collimator to automatic operation after it has been used in the manual mode. The new system will not allow the operator to defeat the automatic feature for work involving the Bucky tray. This improvement will soon be incorporated into the system presently located at the NIH.

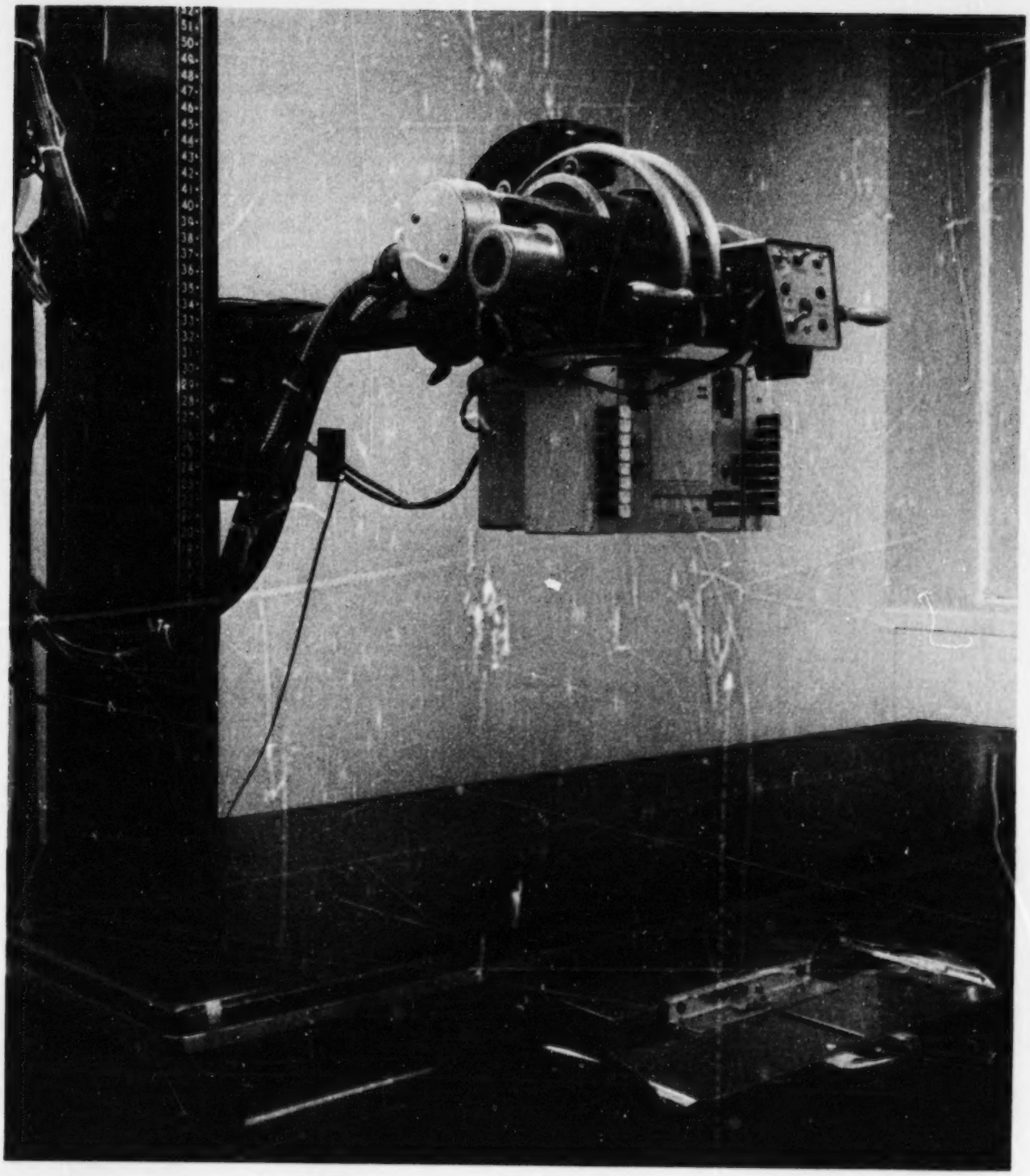

Figure 5. Automatic collimator installed in a clinical radiographic suite

SUMMARY

The 1964 Population Exposure Study by the U.S. Public Health Service revealed that 51 percent of all nondental radiographic examinations involve the chest, 11 percent the upper abdomen, and 14 percent the lower abdomen. Since all of these examinations use either the chest cassette holder or the Bucky tray, an automatic collimating system capable of adjusting the X-ray beam size to film size for these exposures should be applicable to at least 75 percent of the exposures in diagnostic radiology.

A prototype automatic collimator to perform this task was developed by the X-ray Exposure Control Laboratory to prove the technical feasibility of such a device. A second prototype automatic collimation system was also developed at the X-ray Exposure Control Laboratory and installed in the Radiology Department at the Clinical Center of the National Institutes of Health for clinical evaluation. Subsequent use of this device has shown technician acceptance. Modifications, based upon the X-ray technicians' evaluations, were made in the automatic collimator installed at the NIH.

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(*1*) PENFIL, R. L. and M. L. BROWN. Genetically significant dose to the United States population from diagnostic medical roentgenology, 1964. Radiology 90:209-217 (1968).

(*2*) GITLIN, J. N. and P. S. LAWRENCE. Population exposure to X-rays - U.S. 1964, PHS Publication No. 1519. Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402 (1966).

(*3*) WALCHLE, R. L., H. F. STEWART, and J. G. TERRILL. An automatic X-ray field-size limiting system. Radiology 80:105-109 (1967).

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KEY WORDS:
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